Complete Listing of claims

1. (Currently Amended) A method for reducing sensed physical variables including the steps of:

a) generating a plurality of control commands as a function of the sensed physical variables;

b) generating an estimate of a relationship between the sensed physical variables and the control commands, wherein the estimate is used in said step a) in generating the plurality of control commands;

c) sequentially adding a dither signal to each of the plurality of control commands;

d) measuring a response to said step c); and

e) updating the estimate of the relationship based upon said step d).

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2. (Original) The method of claim 1 wherein the dither signal added to each of the plurality of control commands in said step c) differs for each control command.

3. (Original) The method of claim 2 wherein the dither signal added to a given control command includes a triangular signal.

4. (Original) The method of claim 3 further including the step of choosing a direction for the triangular signal in order to avoid saturation for that control command

5. (Original) The method of claim 1 further including the steps of:

f) holding constant the control command to which the dither is added,

g) updating control commands other than the one to which the dither is added according to the function.

6. (Original) The method of claim 5 wherein said step e) is performed only for the control command to which the dither is added.

7. (Original) The method of claim 1 further including the step of determining a magnitude of the dither signal based upon a current magnitude of the control command to which the dither signal is added.

8. (Original) The method of claim 1 further including the steps of:

Varying a frequency of the dither signal to be added to each of the plurality of control commands; and

Extracting the information corresponding to each said control command.

9. (Original) A method for reducing sensed physical variables including the steps of:

a) generating a plurality of control commands as a function of the sensed physical variables based upon an estimate of a relationship between the sensed physical variables and the control commands;

b) updating the estimate of the relationship based upon a response by the sensed physical variables; and

c) varying a size of the update to the estimate in said step b) based upon a magnitude of change over time by at least one of the plurality of control commands.

10. (Original) The method of claim 9 further including the step of selecting between updating or leaving unchanged the estimate of the relationship based upon a magnitude of change by the plurality of control commands.

11. (Original) The method of claim 9 further including the step of:

d) selecting between updating or leaving unchanged the estimate corresponding to a first control command of the plurality of control commands based upon the magnitude of the change in the first control command.

12. (Original) The method of claim 11 further including the steps of comparing the magnitude of the change to a threshold and varying the threshold based upon an estimate of a signal to noise ratio.

13. (Original) The method of claim 9 wherein

the estimate of the change in response $y = \Delta z$ due to a change in control command $v = \Delta u$ at a specific time t_k is denoted T_k,

where T_k is updated according to the equations

$$T_{k+1} = T_k + EK^T$$
$$E = y - T_k v$$
$$K = Qv / (1 + v^T Qv),$$

the matrix Q is a diagonal matrix with elements q_i, and the variables q_i determine the adaptation gain corresponding to the i^{th} control command.

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14. (Original) The method of claim 13 wherein:

a) each variable q_i at each time step is set equal to zero or to some nominal value depending on whether $|v_i| > \delta_i$ where $|v_i|$ is a magnitude of change in the i^{th} control command and the variables δ_i are the deadzone threshold for channel i.

15. (Original) The method of claim 13 wherein:

each variable q_i at each time step is set according to the equation $q_i = \max(q_0, q_v|v_i|^N)$ where q_0 and q_v are parameters chosen for a particular application, $|v_i|$ is a magnitude of change in the i^{th} control command and N is a positive integer.

16. (Currently Amended) A method for reducing sensed physical variables including the steps of:

a) generating a plurality of control commands as a function of the sensed physical variables based upon an estimate of a relationship between the sensed physical variables and the control commands;

b) updating the estimate of the relationship based upon a response by the sensed physical variables; ~~and~~

c) where the control commands ~~and sensed physical variables~~ are filtered to match a filter that has been applied to the sensed physical variables to improve the quality of the estimates prior to said step b); and

wherein a change in the sensed physical variables Δz is related to a change in the control commands Δu by $\Delta z = T(\Delta u)$, the estimate of a sensed physical variable response T is based on Δu and Δz, said method further including the step of filtering Δu to match a known filter on Δz.

17. (Cancel) The method of claim 16 wherein the control commands are filtered to match a filter that has been applied to the sensed physical variables.

18. (Cancel) The method of claim 17 wherein a change in the sensed physical variables Δz is related to a change in the control commands Δu by $\Delta z = T(\Delta u)$, the estimate of a sensed physical variable response T is based on Δu and Δz, said method further including the step of filtering Δu to match a known filter on Δz

19. (Currently Amended) The method of claim ~~18~~ 16 further including the step of low-pass filtering both Δu and Δz to reduce an impact of high-frequency noise on the estimate of T.

20. (New) A system for controlling a plurality of sensed physical variable comprising:

a plurality of sensors for measuring the physical variables;

a control unit generating an estimate of a relationship between the sensed physical variables and a plurality of control commands, and generating the plurality of control commands over time based upon the sensed physical variables and based upon the relationship; and

a plurality of force generators activated based upon said plurality of command signals;

wherein the control unit sequentially adds a signal to each of the plurality of control commands, measures the response to the signal and updates the estimate of the relationship based upon the response.

21. (New) The system of claim 20 wherein the signal added to each of the plurality of control commands by the control unit differs for each control command.

22. (New) The system of claim 21 wherein the signal added to a given control command includes a triangular signal.

23. (New) The system of claim 20 wherein the signal added by the control unit is a dither signal that initially decreases in order to avoid saturation for that control command.

24. (New) The system of claim 20 wherein the control unit holds constant the control command to which the signal is added and updates the control commands other than the one to which the signal is added according to the relationship.

25. (New) The system of claim 24 wherein the control unit updates the relationship only for the control command to which the signal is added.

26. (New) The system of claim 20 wherein the control unit determines a magnitude of the signal based upon a current magnitude of the control command to which the signal is added.

27. (New) The system of claim 20 wherein the control unit varies a frequency of the signal to be added to each of the plurality of control commands and extracts the information corresponding to each said control command.

28. (New) A system for controlling a plurality of sensed physical variable comprising:

a plurality of sensors for measuring the physical variables;

a control unit generating an estimate of a relationship between the sensed physical variables and a plurality of control commands, and generating the plurality of control commands over time based upon the sensed physical variables and based upon the relationship; and

a plurality of force generators activated based upon said plurality of command signals;

wherein the control unit varies a size of the update to the estimate of the relationship based upon a magnitude of change over time by at least one of the plurality of control commands.

29. (New) The system of claim 28 wherein the control unit selects between updating or leaving unchanged the estimate of the relationship based upon a magnitude of change by the plurality of control commands.

30. (New) The system of claim 29 wherein the control unit compares the magnitude of the change to a threshold and varies the threshold based upon an estimate of a signal to noise ratio.

31. (New) The system of claim 30 wherein

the estimate of the change in response $y = \Delta z$ due to a change in control command $v = \Delta u$ at a specific time t_k is denoted T_k,

where T_k is updated according to the equations

$$T_{k+1} = T_k + EK^T$$
$$E = y - T_k v$$
$$K = Qv / (1 + v^T Qv),$$

the matrix Q is a diagonal matrix with elements q_i, and the variables q_i determine the adaptation gain corresponding to the i^{th} control command.

32. (New) The system of claim 31 wherein the control unit sets each variable q_i to zero or some nominal value at each time step depending on whether $|v_i| > \delta_i$ where $|v_i|$ is a magnitude of change in the i^{th} control command and the variables δ_i are a deadzone threshold for channel i.

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33. (New) A system for controlling a plurality of sensed physical variable comprising:

a plurality of sensors for measuring the physical variables; and

a control unit generating and updating an estimate of a relationship between the sensed physical variables and a plurality of control commands, and generating the plurality of control commands over time based upon the sensed physical variables and based upon the relationship;

wherein a change in the sensed physical variables Δz is related to a change in the control commands Δu by $\Delta z = T(\Delta u)$, the estimate of a sensed physical variable response T is based on Δu and Δz, and wherein the control unit filters Δu to match a known filter on Δz.

34. (New) The method of claim 9 wherein the estimate of the relationship is given by $\Delta z = T\Delta u$, where Δz is a change in the sensed physical variables and Δu is a change in the control commands.

35. (New) The method of claim 34 wherein the size of the update is varies in said step c) based upon a comparison of $||\Delta u||$ to a threshold.

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36. (New) The method of claim 35 further including the step of selecting between updating or leaving unchanged the estimate of the relationship based upon the comparison of $||\Delta u||$ to a threshold.